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Potency of Microalgae as Biodiesel Source in Indonesia

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ABSTRACT: Within 20 years, Indonesia should find another energy alternative to substitute current fossil oil. Current use of renewable energy is only 5% and need to be improved up to 17% of our energy mix program. Even though, most of the area in Indonesia is covered by sea, however the utilization of microalgae as biofuel production is still limited. The biodiesel from current sources (Jatropha, palm oil, and sorghum) is still not able to cover all the needs if the fossil oil cannot be explored anymore. In this paper, the potency of microalgae in Indonesia was analysed as the new potential of energy (biodiesel) sources.

Keywords: Microalgae, Biodiesel, Biomass, Indonesia, Alga lipid

1. Introduction

The rapid depletion of current oil reserve will force Indonesia to explore new energy alternative sources such as renewable energy instead of fossil oil. Currently, the use of renewable energy in Indonesia is only 5% from total energy mix, which need to be increased to 17% by 2025. From this target, 5% is expected from biomass energy **[1]**.

The development of biofuel in Indonesia shows interesting trend which is mainly from palm oil, corn oil, coconut oil, jatropha, rubber seed oil and nyamplung. However, the utilization of microalgae for biofuel is still under development. Therefore this paper aims to describe the potency of microalgae as biofuel source in Indonesia.

Microalgae is a unicellular photosynthetic organism (1-400μm) that is potential for fine chemicals **[2]**, food additive, immobilized system for extracellular compound, metal bio-sorption, and CO_2 bio-fixation. Microalgae utilize light to convert Carbon sources and water into biomass-CH_2O and oxygen based on following photosynthetic reaction:

$$CO_2 + H_2O + \textit{light} \rightarrow CH_2O + O_2$$

The CO_2 demand is stoichiometrically about 1.8 kg CO_2/kg dry biomass. For microalgae biomass, higher energy efficiencies for converting solar energy into chemical energy can be achieved. Microalgae can convert up to 5% of the sunlight energy to biomass.

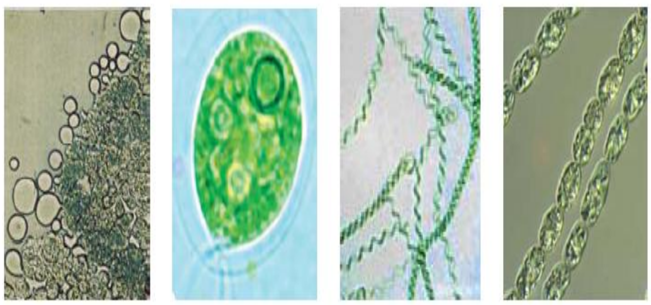

Fig. 1 Type of microalgae

Microalgae have their highest growth efficiencies at illumination intensities of not more than around 100 μE/(m^2s), whereas a sunny tropical day can exhibit values up to 2000 μE/(m^2s). If it is compared to other higher plants, microalgae shows higher productivity of oil per unit area of required land as shown in Figure 2.

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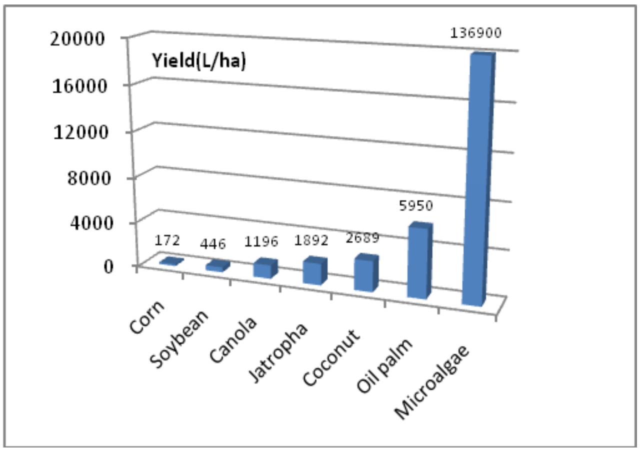


Fig. 2 Microalgae oil productivity compared to other plants

Recently microalgae are used due to its content of lipid, carbohydrate (starch) and protein. Figure 3 shows the direction of biofuel converted from microalgae. Carbohydrate is mainly source for bioethanol production, while lipid for biodiesel. The lipid content of microalgae is shown in Table 1.

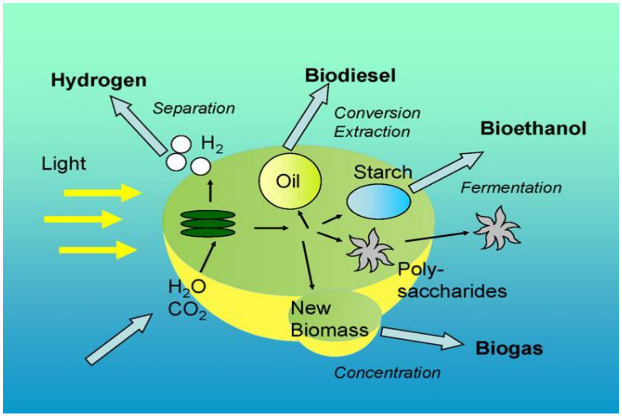


Fig. 3 The potential pathways from microalgae to biofuel

3. Microalgae Production

The common approach to produce microalgae is by using open ponds **[2]**. From this system, up to 15-20 g/(m^{2}d) dry biomass can be harvested. However, open ponds have some disadvantages such as that the cultivation depends on water availability, while in another side evaporation will be a significant barrier due to water loss. Furthermore, the water medium must be extremophiles conditions to some extent to avoid contamination by predator organisms.

In addition, mixing and harvesting in an open pond is less effective due to low cell concentration. This leads to non-economically viability for biofuel products from microalgae. However, since the price of oil significantly higher, this option has to be improved to have better microalgae cultivation.

Compared to open pond, photo-bioreactors has advantages in light distribution. In addition, due to closed system, the evaporation can be reduced completely. Another advantage is that the cell density biomass more than 20 g/L can be obtained. Contamination in the closed system is likely less so different and more productive species can be produced. The limiting factor of this system is high cost and mixing energy. It was reported that more than 3 W/m^2 needed for operating the cultivation.

Table 1
Oil content of algae **[3]**

Microalgae	Lipid content (%)
Botrycoccus Braunii	25-75
Chlorella sp	28-32
Crypthecodinium cohnii	20
Cylindrotheca sp.	16–37
Dunaliella primolecta	23
Isochrysis sp.	25–33
Monallanthus salina	>20
Nannochloris sp.	20–35
Nannochloropsis sp.	31–68
Neochloris oleoabundans	35–54
Nitzschia sp.	45–47
Phaeodactylum tricornutum	20–30
Schizochytrium sp.	50–77
Tetraselmis sueica	15–23

4. The Potency of Microalgae in Indonesia

Geographically, Indonesia lies on equator where sunlight intensity is high. The major parameter limiting algal production process is climate or temperature. Locations with suitable climate conditions encompass area with annual average temperature of 15^{o}C or higher (Figure 4).

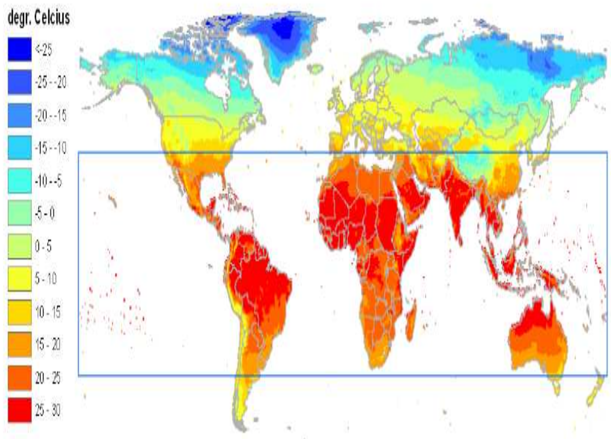
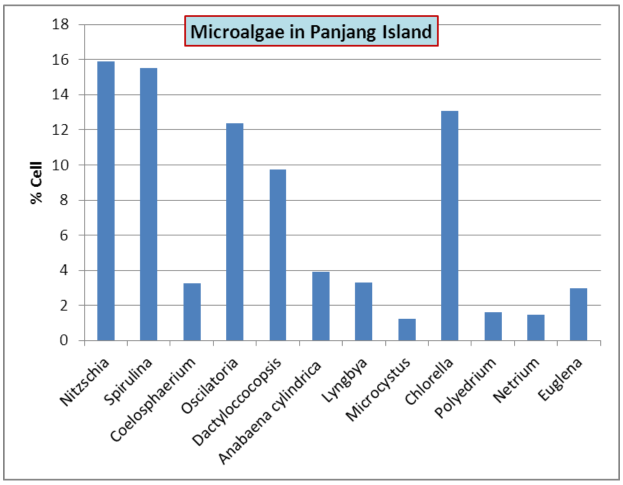
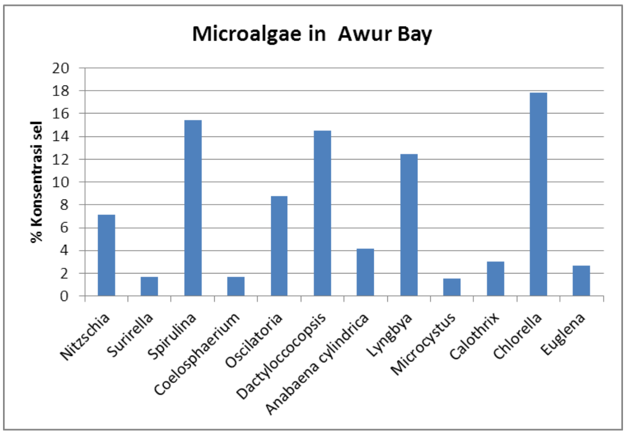


Fig. 4 Suitable climate conditions for microalgae cultivation

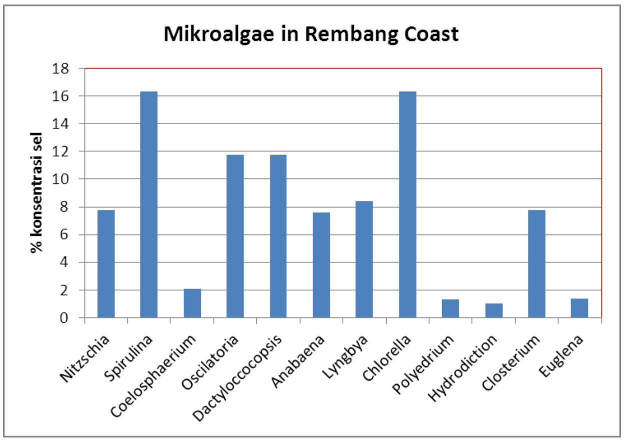
The study of microalgae potential in Indonesia has been done recently in Central Java, in particularly at three locations: Panjang Island, Awur Bay and Rembang coast **[4]**.



(a)



(b)



(c)

Fig. 5 Microalgae identification in Central Java coast (a). Panjang island, (b) Teluk awur dan (c). Rembang coast

Figure 5 shows that in Central Java coast, the microalgae are mostly dominated by *Nitzschia sp., Spirulina sp., Chlorella, Anabaena sp.* dan *Euglena sp.* These five species were analysed for their protein, carbohydrate and lipid contents. It shows that *Chlorella sp., Nitzchia sp.* and Euglena have higher oil content which can be considered as future biofuel sources (Table 2).

Table 2
Protein, Strach and lipid content of selected microalgae

Chemical Composition	Protein(%)	Carb(%)	Lipid(%)
Nitzschia palea	48	23	20
Chlorella vulgaris	58	17	27
Spirulina platensis	63	14	9
Euglena gracilis	61	18	20
Anabaena cylindrica	56	30	7

Chlorella sp. was experienced to be cultivated in a small mini POND system using synthetic medium with following composition: 29.23 g/L NaCl, 1.105 g/L KCl, 11.09 g/L $MgSO_4$ $7H_2O$, 1.21 g/L Tries-base, 1.83 g/L $CaCl_2$ $.2H_2O$, 0.25 g/L $NaHCO_3$, and 3.0 mL of trace metal solution contained 281.3 mg/L $NaNO_3$, 21.2 mg/L NaH_2PO_4 H_2O, 16.35 mg/L Na_2EDTA, 11.8 mg/L $FeCl_3$ $6H_2O$, 37.5 µg/L $CoCl_2$ $6H_2O$, 37.5 µg/L $CuSO_4$ $5H_2O$, 82.5 µg/L $ZnSO_4$ $7H_2O$, 22.5 µg/L Na_2MoO_4, 0.375 mg/L vitamin B_1, 0.188 µg/L vitamin B_{12}. The mini pond system was built to mimic real pond system with a ratio L/D=10 (Figure 6).

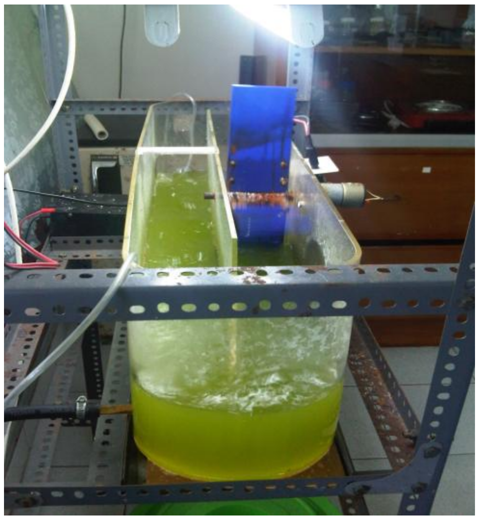
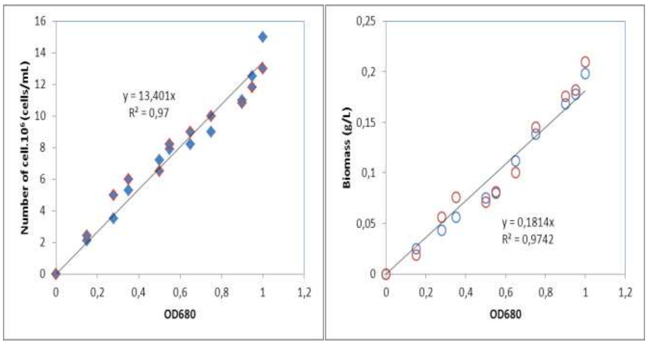


Fig. 6 Mini pond system for algae cultivation



(a) (b)

Fig. 7 Correlation between optical density and number of cell (a) and Optical density and Biomass (b)

The cultivation of *Chlorella* has been done within 14 days under temperature and pH constant. The mixing was generated by a paddle wheel with velocity 10 rpm.

$$CellNumber(sel/mL) = 13.4x10^{6} OD_{680}$$

Figure 7 show the correlation of optical density, number of cell and biomass which then can be transferred into following equations:

$$Biomasa(g/L) = 0.1814 \cdot OD_{680}$$

$$Biomasa(g/L) = 1.35 \cdot 10^{-8} Number\ of\ cell(sel/mL)$$

The growth of *Chlorella* is shown by Figure 8 as function of cultivation time and paddle wheel velocity. It shows that the rotation of paddle wheel give significant of cell growth due to reducing cell sedimentation at the bottom of pond and also to increase the light distribution to the cells **[5, 6]**.

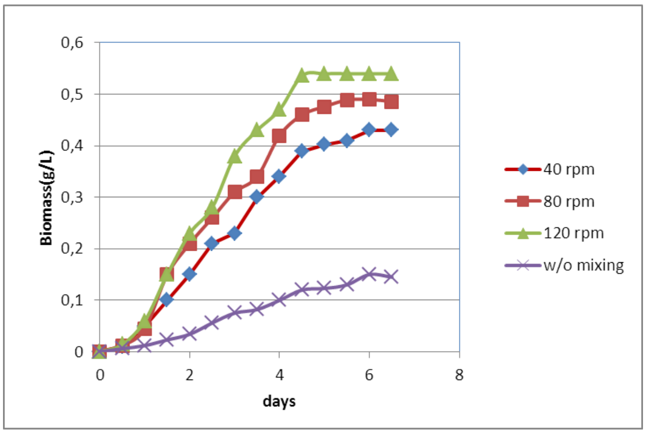


Fig. 8 The growth rate of *Chlorella sp* in mini pond system.

5. Microalgae Biomass to Biodiesel

Conversion of Algae biomass to biodiesel is performed through trans-esterification reaction (Figure 9).

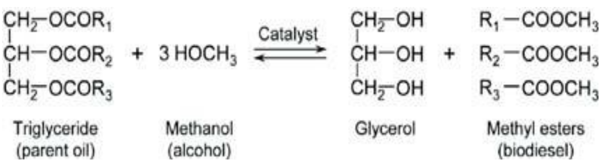


Fig. 9 Esterification reaction of oil to biodiesel

In this reaction, we need 3 moles of alcohol for each mole of triglyceride to produce 1 mole of glycerol and 3 moles of biodiesel. However, to ensure that all triglyceride is converted to biodiesel, the methanol is used excess (6 moles). The yield of biodiesel exceeds 89% on a weight basis.

The characteristic of algae biodiesel is shown in Table 3 while the production is shown in Figure 9.

Table 3
Physical properties algae biodiesel

Variable	Value
Acid number	0.15-0.4 mg KOH/g
Density	0.89 g/mL
Iod number	109 %

Fig. 9 Biodiesel products from microalgae

6. Conclusion

As coastal country, Indonesia has high potential for microalgae cultivation. The microalgae are considered for biofuel production. The microalgae which have high oil content (20-30%) are: *Nitzschia palea (23), Chlorella vulgaris* (27*)*, *Euglena gracilis* (20) which were identified at Panjang island, Teluk Awur, and Rembang coastal.

Acknowledgement

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